REMARKS

This paper is in response to the final Office Action mailed July 10, 2006. By this paper, claims 1, 6 and 15 are amended. Claim 13 was previously cancelled. Therefore, claims 1-12 and 14-20 are pending upon entry of this paper.

Response to Rejection of Claim 1

Claim 1 is directed to a physical vapor deposition (PVD) method for deposition of dielectric materials, including low dielectric constant (low-k) materials, onto substrates during the fabrication of integrated circuits and other electronic, opto-electronic, microwave, and micro electro-mechanical (MEM) devices. The method includes the steps of forming an energized monochromatic ion beam, converting said ion beam into an energized monochromatic beam of neutrals, directing said beam of neutrals toward a sputtering target, exposing said target to bombardment by said beam of neutrals; sputtering particles from said target, forming a cloud of said sputtered particles proximate to a substrate, and depositing said sputtered particles onto said substrate. More particularly, claim 1 is directed to a method for the physical vapor deposition of dielectric material onto a substrate comprising, *inter alia*:

> converting said ion beam into an energized monochromatic beam of neutrals by passing the ion beam through a charge transfer chamber containing a volume of neutrally charged gas atoms or molecules, wherein the neutrally charged gas atoms or molecules are slower moving relative to said ion beam, such that said relatively fast moving positively charged ions collide with said relatively slow moving neutral gas atoms or molecules inside said charge transfer chamber such that said collision events cause said positively charged ions to acquire an electron from said slow moving neutral gas atoms or molecules.

Claim 1 in the application stands rejected as being anticipated by the non-patented literature Albertinetti et al. Claim 1 is novel and patentable over the references of record, and particularly over Albertinetti et al., because the cited art does not show or suggest a method for the physical vapor

deposition of dielectric material onto a substrate comprising converting an ion beam into an energized monochromatic beam of neutrals as required by claim 1.

Albertinetti et al. discloses a method of forming dielectric SiO2 and TiO2 films on a substrate using PVD. As recognized by the Examiner, a Kaufman-type ion gun with grid optics was used. The ion beam space charge is neutralized by electrons from a plasma bridge neutralizer (PBN) or hollow cathode neutralizer (HCN). Albertinetti et al. states that "[t]he PBN was mounted on the face of the ion gun" (which is to some degree similar to teaching of the previously discussed Katsube et al. apparatus) while "[t]he HCN was mounted on the wall of the chamber, and it pointed towards beam axis". Albertinetti et al., page 5621. It was also stated that "[t]he HCN was positioned in the way to neutralize both the sputter beam and the beam from the ion assist gun". Albertinetti et al., page 5621 (emphasis added). Although, the information about the HCN mount is very limited and sketchy, it is still clear that the neutralizing electron beam from the HCN did not coincide with the ion beam axis (path), but instead the neutralizing electron beam from HCN crossed the ion beam at some (unspecified) angle. This approach of mounting HCN is believed to be very typical since electrons from HCN will have trajectories which would never be intercepted by either the target or the substrate. This reduces the amount of heat the target or growing film on the substrate is exposed to.

However, Applicant disagrees with the Examiner's opinion that ion beam is converted into a beam of neutrals by the PBN or HCN as neutralizing a beam as described in the Albertinetti et al. reference is not the same as converting the beam to a beam of neutrals as required by claim 1. It is well known that the primary function of neutralizers with Kaufman-type sources is to compensate the space charge of ion beam to prevent beam divergence due to the low ion energy (50 – 2000 V) and high current density (0-350 mA). (The voltage/current data for a Kaufman-type ion gun manufactured by Ion Tech Inc. with an 11 cm DC ion source (as used in the Albertinetti et al. reference) was obtained from the Veeco Instruments Web site). It is known that passing an ion beam through a vacuum chamber (chamber pressure of 0.5 - 1.0x 10^{-4} Torr as taught in Albertinetti et al. can be considered a relatively good technical vacuum) when the beam has high current density and low ion energy (low accelerating voltage), that the beam will spread out due to the repulsing effect of positive charge of ions forming the beam. This repulsion causes the beam cross-sectional

diameter to increase. Typically, to compensate for this positive space charge, a beam of electrons is injected into this positive space charge of ions. The electron beam neutralizes the positive space charge of ions by adding an "equal" amount of negative space charge produced by the electrons. In this case, the both beams "coexist" together with relatively low near-field intercalation (mutual recombination) but they have very effective far-field interaction based on Coulomb Law, which glues opposite charges together still maintaining them at some physical distance one from another. The result is the space charge of the ion beam is neutralized so that the ion beam does not spread any more. However, the individual ions maintain their original charge energy and momentum.

Applicant agrees with the Examiner's characterization that Albertinetti et al. discloses the "bleeding of O_2 into the chamber". However, Applicant strongly disagrees that this citation or related argument is relevant to converting the ion beam into an energized monochromatic beam of neutrals as required by claim 1 and as defined in the specification. It is believed that oxygen is added in the Albertinetti et al. teaching for the purpose of oxidation of the growing film during reactive sputtering. The addition of oxygen is not intended for charge neutralization of Ar ions of the original beam since the cross-section of interaction of charge transfer from an oxygen molecule to an argon ion is extremely small, essentially equal to zero. Applicant believes that it is impossible to break a bond in an O_2 molecule and move a valent electron to the Ar ion to neutralize it. The low thermal energy of the oxygen molecule does not help in the transfer of electrons to the argon ions. Conversely, according to present invention, the low energy of the gas atoms or molecules, such as Ar, provides efficient interaction between the Ar atoms and ions actively promoting conversion of the fast argon ions (of the beam) into fast atoms by means of a resonance charge transfer process. It is believed for this type of neutralization to occur, the charge transfer chamber must have a higher Ar pressure than taught by Albertinetti et al, which is realized inside the restricted volume of charge transfer chamber. The chamber isolates a zone of high Ar pressure inside it from the low Ar pressure outside. There are no free electrons or plasma inside the charge transfer chamber according to present invention. Rather, there are only Ar ions and atoms inside charge transfer chamber that makes it different from the teachings of Albertinetti et al, which uses PBN or HCN.

Therefore, the present invention uses a very different approach of converting the ion beam into an energized monochromatic beam of neutrals. The principal difference is in utilization of a

charge-transfer chamber as defined in the specification to convert fast ions into neutral atoms along the path of beam propagation. As shown in Fig.1 of the application, the monochromatic ion beam, which has a nearly zero fast atom component in the vicinity of the either side of ion optics aperture 2, propagates along charge-transfer chamber 3, which is filled with a gas, such as rarified Ar gas. The pressure of rarified gas inside chamber 3 is not equal to the near vacuum taught in the Albertinetti apparatus. Instead, the pressure inside of chamber provides a charge-transfer collision process between fast Ar^+ and low energy Ar^0 atoms. As set forth in the specification, an ion energy in the range of 100-400 eV provides a preferable cross-section for charge transfer collision process between Ar^+ and Ar^0. Nowhere does Albertinetti et al. teach or suggest converting the ion beam into a beam of neutrals.

Applicant submits that the remaining references cited by the Examiner, including Katsube et al, Saito et al., Harper et al., Mattox, also do not teach converting the beam into a beam of neutrals, and therefore cannot cure the deficiencies of Albertinetti et al.

Accordingly, claim 1 is not anticipated by or made obvious by the cited reference and favorable consideration of claim 1 is respectfully requested. Claims 6 and 15 contain limitations similar to the one described above. Therefore, these claims are patentable for at least the same reasons. Claims 2-5, 7-14 and 16, depending directly or indirectly from one of claim 1, 6 or 15 are submitted as patentable over the cited references for at least the same reasons.

Response to Rejection of Claims 12 and 15

Claims 12 and 15 recite that the step of converting the ion beam into an energized monochromatic beam of neutrals is performed by directing the ion beam through a charge transfer chamber containing a volume of relatively slower moving neutrally charged Ar gas. Nowhere does the Examiner claim that the cited art teaches or suggests this limitation. Therefore, it is believed that this limitation further distinguishes these claims over the cited art.

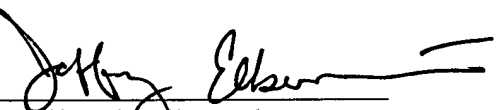
Conclusion

In view of the remarks made herein, Applicant submits that the claims presented herein are patentably distinguishable from the art applied and prompt allowance of the application is respectfully requested.

Should the Examiner determine that anything else is desirable to place this application in even better form for allowance, the Examiner is respectfully requested to contact the undersigned by telephone.

Respectfully submitted,

WEGMAN, HESSLER & VANDERBURG

By 

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